River Clyde Environmental Flow Assessment

Summary Report to DPIWE, Water Management Branch

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Introduction

The River Clyde flows from the outlet of Lake Crescent in the Central Highlands, via the townships of Bothwell and Hamilton, to the Derwent River. The catchment has experienced extensive clearing, especially in its middle and lower sections, and is subject to varying intensity of landuse. Grazing production is supplemented by irrigation, frequently involving flood irrigation of pasture, and water management is seen as a critical aspect of agricultural production in a catchment which frequently experiences very dry summers. As a consequence, water management, particularly with regard to storage and releases from the Lake Sorell-Crescent system, has been in place since the mid-1800s and has been intensive for over 50 years. The magnitude and seasonal pattern of baseflows (flows between major flood events) in the Clyde are largely dictated by managed lake releases and downstream abstractions during the majority of the year.

An environmental flow assessment was conducted for the River Clyde during the development of the River Clyde Water Management Plan (DPIWE 2004). This document summarises the work conducted and the main results. The study was conducted iteratively while both the River Clyde and the Lakes Sorell and Crescent WMPs were being developed, due to the need for integration of the environmental water requirement assessment for the river with that of the Lake Sorell and Clyde system, in its headwaters. The final result was therefore a trade-off between water management implications for the lake and river environments.

2. Methods

The environmental flow assessment examined both baseflows (minimum flows) and high/flood flow events, in order to describe an environmental flow *regime*, consistent with the approaches being taken elsewhere in the state.

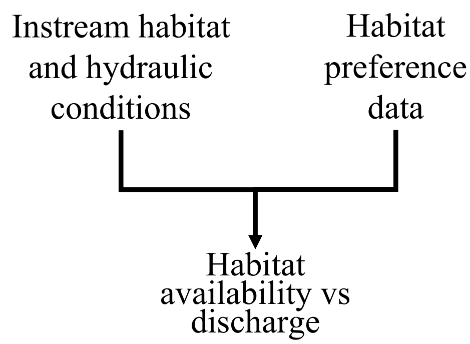
The minimum flow assessment was conducted using the risk-assessment approach adopted by DPIWE from the work of Davies and Humphries (1996). It is the same method used in the initial minimum flow assessment conducted for the River Clyde by Davies (2001), which this report supercedes and replaces.

By this method, risks of loss of habitat for instream fauna and flora are assessed for a range of flows relative to the habitat available under a reference flow regime. A reference flow record is used because :

- flow is the main factor which determines the types, amount and distribution of instream habitat for the aquatic biota;
- we either have historical flow data or we can model it, but there is rarely any historical data on instream habitat or biota;
- assuming that the overall pattern in instream habitat is dependent on flow, and that channel dimensions do not change substantially, we can validly compare habitat available at different flows.

As a result we can use changes in flow as a surrogate to measure changes in habitat availability, provided we have information on how habitat varies with flow. The reference flow regime can be selected to represent either natural or historical conditions, depending on the management objective of a water management plan.

The minimum flow assessment is based on relationships between habitat availability for key river species and flow. These are developed by combining information on actual habitat available in the river with the habitat requirements (preferences) of the species, as follows:



2.1 Instream habitat data

Instream habitat features are recorded in the river, in two steps:

1. Reaches of the river which are representative of the range of habitats found in larger river sections are chosen. Each of these is called the ‘study reach’. Two such reaches had been selected in the River Clyde by DPIWE – one at Blacksnake Plains, downstream of Lake Crescent, and the other at Humbie, downstream of Bothwell (see Figure 1).

2. Surveys are conducted at a number of locations within the study reach. ‘Transects’ or survey lines are run across the river at locations that represent typical habitats within the reach. The channel profile, water depths and velocities, and substrates (river sediments) are recorded across these lines at regular intervals. The transects are also ‘linked’ together by surveying.

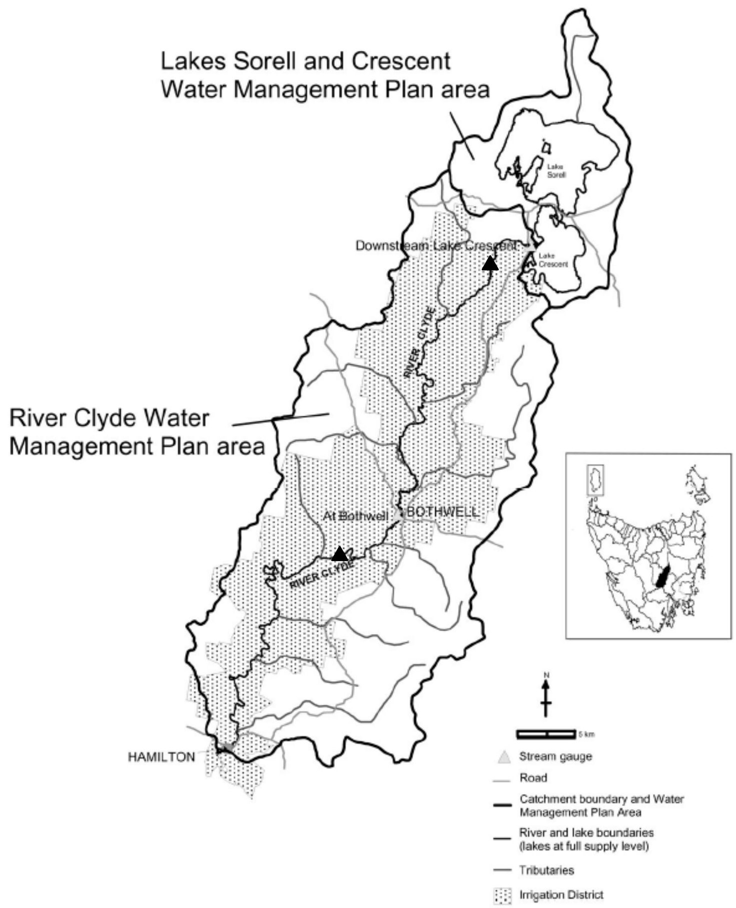


Figure 1. Map of Clyde catchment showing Water Management Plan areas, and with environmental flow assessment study reaches indicated (black triangles).

2.2 Habitat availability at particular flows

The available instream habitat for important (key) species in the river is then assessed in

1. The 'key' species are identified by reviewing the community values, existing information on the biology of the river and, if necessary, by conducting a survey of the biota. For the Clyde, a list of community values already existed (See box on next page), a number of fish and invertebrate surveys had been conducted, there was data on the distribution of plants and threatened species, and data on the brown trout fishery collected by the Inland Fisheries Service.

2. Information on the habitat requirements of the key fish and plant species and platypus is compiled from existing data sets and the scientific literature. For the

macroinvertebrates (aquatic insects, crustaceans, snails etc), samples are collected from the river over a range of habitat conditions and used to develop data on habitat requirements.

3. The data on habitat requirements (known as 'habitat preference' data) is combined with the data on the actual habitat in the river (from the study reaches) to calculate an index of available habitat over a range of flows. This is done using a software package called 'RHYHAB', developed in New Zealand. The index of available habitat is known as the 'weighted useable area' index or WUA, and is measured in m^2 of habitat per m of river length.

2.3 The risk assessment process

2.3.1 Reference flows

A reference flow condition is selected, and flow records for that condition are generated. For example, if the reference condition is selected to be equivalent to natural, then the natural flow records for the river must be provided. This might be from old (pre-development) flow records, or it might be modelled based on rainfall runoff models and data from other catchments.

Selecting the appropriate reference condition is critical, as the final results depend on risks determined as the degree of departure form the reference condition. For the Clyde, a number of possibilities existed for an appropriate reference condition:

- 'natural catchment and lakes' – the flow regime in the river before European development ie without flow regulation and without any modification or management of the lakes.
- 'historical catchment and lakes' – the flow regime as a result of lake and irrigation management in place over the last few decades;
- 'natural' catchment and 'historical' lakes – the flow regime that represents natural input from the catchment combined with historical pattern of flow releases from the lakes;

Community Values for the River Clyde. Supplied by DPIWE – derived from a community workshop in Bothwell conducted in August 1998. Note values underlined are those of relevance to environmental flow management.

WATER VALUES	PRIORITISATION OF VALUES
1. Ecosystem	
Maintain carp free status of river.	1
<u>Maintain and improve habitat for aquatic fauna.</u>	<u>2</u>
<u>Improve fish habitat.</u>	<u>2</u>
<u>Maintain and improve habitat for macroinvertebrates.</u>	<u>2</u>
<u>Improve status of endangered species.</u>	<u>2</u>
<u>Maintain eel habitat.</u>	<u>2</u>
<u>Improve water quality.</u>	<u>3</u>
Stop sewage outflows into river.	3
Selectively eradicate willows.	4
Remove cumbungi.	4
<u>Improve natural seasonality of flows.</u>	<u>4</u>
<u>Maintain and improve fish habitat.</u>	<u>4</u>
2. Consumptive and non-consumptive use	
Security of supply of town water supply.	1
High security of riparian water.	2
High security of water for irrigation.	3
Allow for increased irrigation through various methods.	4
Improve efficient regulation of water flows.	4
Provision of water for power generation.	5
Provision of water for fish farms.	5
3. Recreational	
<u>Maintain and improve spawning areas for trout.</u>	<u>1</u>
<u>Improve trout fishery.</u>	<u>1</u>
Maintain access to river for disabled fishermen.	2
Improve for swimming.	3
4. Physical Landscape	
Control or eradication of crack willow.	1
Improve the riparian zone.	1
Maintain stability of river.	2
Maintain critical barriers to stop invasion of undesirable species.	3
Preservation of Bothwell Falls.	4
Allow for flood mitigation.	5
5. Aesthetic	
Improve visual access of Croakers Alley.	1
Maintain or improve Clyde River Walk at Hamilton and Showgrounds.	1
<u>Improve visual quality and access to Bothwell Falls.</u>	<u>2</u>
Reduce turbidity of river.	3

- with or without lake inputs – the lake system has been intensively managed for water supply downstream for many decades. Inclusion of lake outflows in the environmental flow analysis would mean that they are recognised as part of the environmental flow regime. It is difficult, however, to justify the use of an entirely 'natural' lake flow regime in environmental flow management, as both the lake and downstream river ecosystems have adapted to the historical pattern of lake releases.

All of these options were explored, but it was finally agreed that the following reference condition was the most appropriate:

- 'natural downstream catchment flows' – natural catchment input from the catchment into the River Clyde in the absence of any lake inputs. This reference flow is derived by modelling the natural (without abstractions) pickup from the catchment into the Clyde below Lake Crescent. This recognises the fact that lake inputs are (and have been from many years) highly managed, and separates the provision of environmental flows in the river from the influence of additional flows input (and subsequently abstracted) for irrigation. This effectively divorces environmental flow management in the river from flow releases from Lake Crescent. It also shifts the concept of reference toward one where minimum flows are based on natural downstream catchment input alone and thus can only be used to set a 'refuge flow' for aquatic biota.

This decision was reached after discussions within the WMP Consultative Group regarding the problem of impacting on both security of supply and lake environmental values if environmental flows for the river are supplied or significantly supplemented by lake releases.

Flow data was generated for this reference condition by Bryce Graham (Hydro Tasmania) under contract to DPIWE Water Assessment and Planning. The median and the 20th percentile of mean daily flows was calculated for each month for the entire period of record (1/1/1970 to 30/12/2002, Figure 2) – these were the monthly reference flows used in the risk assessment to define the minimum environmental flows for normal and dry conditions , respectively.

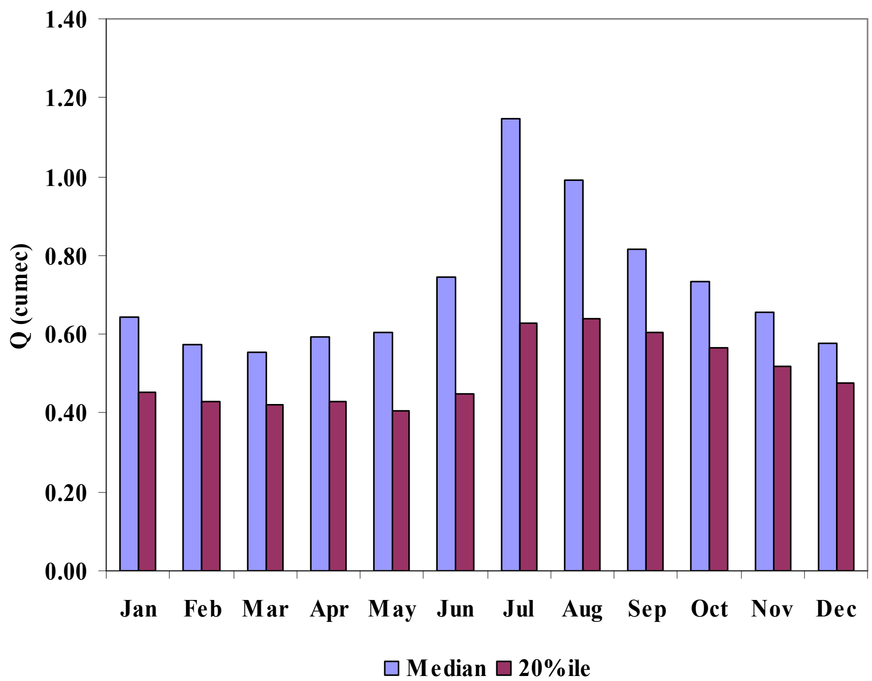


Figure 2. Reference flows used in minimum environmental flow assessment - median and 20 percentile values for mean daily flows for each month (period of record 1/1/1970 to 30/12/2002).

All flow data used for this study was from or based on flow data from the Bothwell flow gauge.

2.3.2 Habitat area differences

For each month, the habitat area for a species is determined using the monthly reference flow and the habitat preference data. This gives a single reference habitat value for that species. The habitat area available is calculated for each of a series of individual flow values, ranging from 0 cumec up to the historical median monthly flow. Each of these are compared, as a percentage, to the reference habitat area, as in the following equation:

$$\%\Delta HA = 100^{*}\ (WUA_{Qn}\text{-}WUA_{Qref})/WUA_{Qref}$$

Where %ΔHA is the % change in habitat area; WUA_{Qn} is the habitat area at one of the individual flow values, and WUA_{Qref} is the habitat area at the monthly reference flow.

These calculations are repeated for each species.

2.3.3 Risk assessment

The final step is to tabulate all the values of %ΔHA for all the species, by month. The largest value of %ΔHA (ie the largest habitat loss) is then selected for each individual flow value. These figures are then converted into a risk level ranging from I to IV, as follows (Table 1):

Table 1. Risk category criteria for biological values in the River Clyde. %ΔHA = % difference (positive or negative) in WUA between nominal flow and reference flow.

Risk category:	I	II	III	IV
Biological Values	**No risk or beneficial**	**Moderate risk**	**High risk**	**Very high risk**
Total macroinvertebrate abundance and number of taxa; trout life stages; wetted area of stream bed.	> - 15% %ΔHA change from reference flows i.e. > 85% of habitat under reference flows	- 40% to -15% %ΔHA change from reference flows i.e. 60 – 85% of habitat under reference flows	- 70% to -40% %ΔHA change from reference flows i.e. 30 - 60% of habitat under reference flows	< - 70% %ΔHA change from reference flows i.e. <30% of habitat under reference flows
Individual macroinvertebrate taxa.	< 10% of taxa with %ΔHA < -25% i.e. with < 75% of habitat under reference flows	10 - 25% of taxa with %ΔHA < -25% i.e. with <75% of habitat under reference flows	25 - 50% of taxa with %ΔHA < -25% i.e. with <75% of habitat under reference flows	> 50% of taxa with %ΔHA < -25% i.e. with <75% of habitat under reference flows

This results in a single risk level being assigned to every flow increment for each month of the year.

2.3.4 Minimum environmental flow requirement

For each month, the lowest flow which falls within the no risk band (Band I) is then selected to represent the minimum 'no risk' environmental flow requirement for that month. The same process is applied to the 'moderate risk' band (II), and the 'significant risk' band (III).

These minimum environmental flow requirements represent *the long term median of mean daily flows* which should be sustained in order to result in 'no risk', 'moderate risk' or 'significant risk' to the aquatic biota, in each month of the year. They do not represent a single value which should be sustained at all times, as this is both impractical and unrealistic. Compliance should be focused on maintaining the recommended values as long term medians.

2.3.5. Dry condition flows

A set of environmental flows is derived as above using medians of monthly mean daily flows. Those flows are suitable for most 'normal' flow conditions. However, for persistently dry conditions, a set of lower values is also provided, recognising that the river would naturally experience low flows.

The analysis described above is repeated, but using the 20^{th} percentile (rather than the median) of monthly mean daily reference flows to calculate WUA_{Qref} values. The risk assessment is then conducted using these values to derive a new set of dry condition minimum flow values.

A set of trigger flows is used to operationalise the conditions under which these flow apply. These are set to be equal to the dry condition reference flows ie the 20^{th} percentile of monthly mean daily reference flows.

2.4 High/Flood flow events

Four types of high flow/flood event were evaluated for the River Clyde:

- Biennial or median flood – for channel maintenance;
- Annual flood – channel maintenance and sediment movement;
- Flushing and trigger high flows – silt flushing, fish migration and spawning;
- Freshes – flushing algae and sustaining riparian plants.

A minimum set of these events was derived by inspection of the historical and modelled reference flow records for the Clyde. Each event was defined with a magnitude, frequency, timing, and duration.

In addition, flow required to flush fines (silts) from the streambed were assessed by modelling, using the RHYHAB package for the Humbie study reach.

2.5 Trout spawning

A key community value for the River Clyde is the trout fishery (see next section). Information was needed on the conditions required for spawning for brown trout in the river and its relationship to flow. A series of field observations were made of the distribution of spawning habitat (gravel substrate) within the mainstem of the Clyde, between Lake Crescent and Hamilton. Transects were established at three representative sites within the main spawning reach of the river (upstream of Bothwell), where gravel substrate was most abundant (the presence of gravel is limited in most other reaches). The channel profiles at these sites were surveyed and water levels recorded over a range of river discharges.

Flows required to support spawning habitat and maintain egg nests (redds) in the gravel were assessed, using RHYHAB to model flows between those measured in the field.

3. Results

3.1 Aquatic values, objectives and reference flows

The Draft River Clyde Water Management Plan (DPIWE 2004) has the following objectives (among others), to:

- preserve low flows in the river to maintain sufficient habitat and water quality to sustain the river ecosystem health and populations of aquatic biota including fish;
- preserve a range of flood flows in the river to maintain the channel form and transport sediment and organic material through the system; flush fine sediment, nutrients and algal blooms; and stimulate fish spawning;

The key aquatic values for the catchment identified by the community of direct relevance to environmental flow management include sustaining the presence and condition of native aquatic fauna and flora, especially benthic invertebrates and eels, and the brown trout population and fishery.

Surveys of the Clyde have indicated a fish fauna primarily comprised of exotic fish – brown trout, redfin perch, tench, while the only native fish species of note is the shortfin eel, *Anguilla australis* – whose population is primarily sustained through stocking and transfers. A platypus population is also known to occur in the river.

Results of an assessment of the condition of the River Clyde brown trout fishery was presented to the Consultative Committee for the Clyde WM Plan (Davies unpub. data), with the conclusion that:

- the brown trout fishery has experienced a severe decline since the early 1990;s;
- the decline is correlated with, and believed to be at least partially caused by, a decline in spring river flows since the late 1980's, which were not related to changes in rainfall.

An illustration of the decline in the fishery is shown in Figure 2 (data from the Inland Fisheries Service). These data are strongly correlated with the incidence of low flows in the September to October period (Davies unpub. data).

Figure 2. Mean catch per day in the River Clyde for brown trout over the angling season for the period 1984/85 to 2000/01. (Data sourced from the Inland Fisheries Service questionnaire database).

Sustaining the aquatic invertebrate, platypus and eel populations of the Clyde requires protection of sufficient minimum flow to maintain refugial habitat, avoid high temperatures and low dissolved oxygen, and to maintain connectivity between various sections of the river. It also requires the maintenance of a high flow/flood regime that sustains the river ecosystem by transporting organic matter, sediments and algae, and that provides migration stimuli for fish (eels).

Sustaining the brown trout population requires minimum and high flows as above, as well as flows to provide access to spawning areas (gravel within and adjacent to the main river channel). In addition, a minimum flow must be sustained during the September-October period in order to protect hatched larval trout (alevins and fry) present in the egg nests (redds) in the stream bed, from 'dewatering' and subsequent mortality.

Overall, the objectives of the WMplan can be met, and the community values protected, if the following environmental flow elements are protected:

- a set of minimum flows, which vary monthly, to provide protection of habitat, water quality and ensure connectivity; and

- a set of high/flood flow events, with the following roles:

Flood	Role
Median	Channel maintenance.
Annual	Channel maintenance, sediment and coarse organic material transport.
Flushing and Trigger	Flush silts. Maintain habitat for invertebrates and trout spawning. Maintaining trout eggs and invertebrate habitat
Freshes	Flush algae and fine organic material, maintain riparian vegetation and plant germination.

3.2 Minimum environmental flows

3.2.1 Normal conditions

Under normal (> 20% percentile flow) conditions, the following minimum environmental flows should be sustained as long term medians:

Table 2. Minimum environmental flow requirements (ML/day) under 'normal' (median) conditions, at Bothwell.

Month	No risk	Moderate Risk	High Risk
Jan	45.4	33.7	< 33.7
Feb	40.6	32.0	< 32
Mar	40.6	32.0	< 32
Apr	42.3	33.7	< 33.7
May	42.3	34.6	< 34.6
Jun	52.7	38.9	< 38.9
Jul	79.5	58.8	< 58.8
Aug	66.5	49.2	< 49.2
Sep	61.3	42.3	< 42.3
Oct	52.7	38.9	< 38.9
Nov	45.8	32.0	< 32
Dec	42.3	32.0	< 32

3.2.2 Dry conditions

Under 'dry' (< 20 percentile flow) conditions, the minimum environmental flows shown in Table 3 should be sustained as long term medians.

Trigger values are used to initiate the application of these dry condition environmental flows. When daily flows at the Bothwell gauge 'without abstraction' (ie adjusted for any takes) fall to the trigger values, the dry condition environmental flows apply. Once the daily flows at the Bothwell gauge 'without abstraction' (ie adjusted for any takes) rise above the trigger values, the 'normal' condition environmental flow values apply.

Table 3. Minimum environmental flow requirements (ML/day) under 'dry' conditions, at Bothwell. See text for explanation of trigger values.

Month	No risk	Moderate Risk	High Risk	Trigger
Jan	34.6	29.4	< 29.4	39.0
Feb	32.4	24.2	< 24.2	37.0
Mar	32.4	24.2	< 24.2	36.4
Apr	32.4	24.2	< 24.2	37.2
May	32.8	23.3	< 23.3	35.1
Jun	32.8	24.2	< 24.2	38.7
Jul	42.3	34.6	< 34.6	54.2
Aug	45.8	34.6	< 34.6	55.4
Sep	42.3	33.7	< 33.7	52.1
Oct	41.5	32.0	< 32	49.0
Nov	37.2	30.2	< 30.2	44.7
Dec	34.6	29.4	< 29.4	41.1

3.3 High/Flood flows

A series of high and flood flow events was identified by inspection of the historical and modeled flow records. Results of flow modeling at Humbie to assess flow needed for flushing of silts were also used. Events of the order of 5 cumec (ca 430 ML/day) provide a satisfactory level of silt flushing from both the surface and sub-surface of the stream bed at the Humbie site (Figure 3).

The final recommended high/flood environmental flow events are shown in Table 3, with their recommended minimum magnitudes, frequencies, timings and durations. These event should be regarded as a 'minimum set' ie these are the minimum required to maintain the ecological and community values of the river – in combination with the minimum flows described above.

As for the minimum flows, some flexibility is to be expected such that the frequency of events recommended in the table should be the average over a 5 to 10 year period. It is not practical for these events to be expected every year. Provided the flow history over a 5 – 10 year period includes events of at least these magnitudes, frequencies and durations, then the recommendations will have been satisfied. A +/- 10% tolerance can be applied to the magnitude of the high flow/flood events. There is also provision for scaling these events to suit prolonged dry periods if that is deemed necessary.

Some floods may satisfy more than one purpose and may not be required more than once. For example, if a 1300 ML/day event passes the Bothwell gauge in May, the biennial, annual, flushing and May fresh flows for the year are all considered to have been met by that single event.

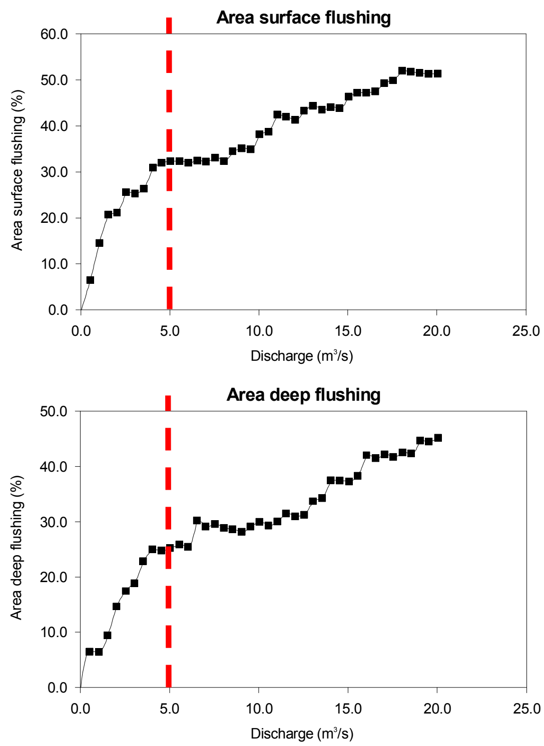


Figure 3. % of stream bed flushed (surface and sub-surface) over a range of flows at the Humbie study reach in the River Clyde. Dashed line indicates a 5 cumec flood event.

Table 3. Recommended minimum set of high/flood environmental flow events for the River Clyde (at Bothwell).

Type of flow provision	Purpose of flow	Period in which the flow is required, and frequency of flow	Magnitude of flow measured at Bothwell	Duration of flow required
Biennial flood	• Channel maintenance	Any time of year, once every 2 years	15 cumecs (1300 ML/d)	2 days
Annual flood	• Channel maintenance • Transport sediment and coarse organic material through the system	May-Oct, once every year	9 cumecs (780 ML/d)	24 hours
Flushing flow	• Flush silts through the system. • Maintain habitat for invertebrates and fish spawning.	May-Jun, once every year	4.5 cumecs (390 ML/d)	24 hours
Trigger flow	• Maintain invertebrate habitat and fish eggs	Jul-Aug, once every year	4.5 cumecs (390 ML/d)	24 hours
Fresh	• Flush algae and fine organic material • Maintain riparian vegetation and plant germination	Nov-May, once each month	1 cumec (86 ML/day)	24 hours

3.4 Absolute minimum flows

While the recommended minimum and high/flood flows should be applied under all normal and dry season circumstances, an absolute minimum flow at Bothwell has also been identified. This was evaluated by assessing (by modelling the study reach transect data, and using the RHYHAB package):

1. connectivity and available width of fish passage;
2. rates of change of wetted perimeter with flow;
3. temperature vs flow (under a range of worst case summer high temperature conditions).

At very low flows, stream temperature does not vary with flow, but is dictated by air temperature, insolation, sunshine hours and evaporation (windspeed and humidity). Both wetted perimeter and the minimum wetted width of the channel vary strongly with flow at these flows however (Figures 4 and 5). An absolute minimum of 10 ML/day (0.12

cumec) is required to protect the channel from loss of pools and loss of connectivity for fish passage (required to ensure that fish do not become restricted to pools of low water quality under very low flow conditions).

An absolute minimum flow of 10 ML/day is recommended at the Bothwell gauging station. This should be scaled up by catchment area for locations further downstream.

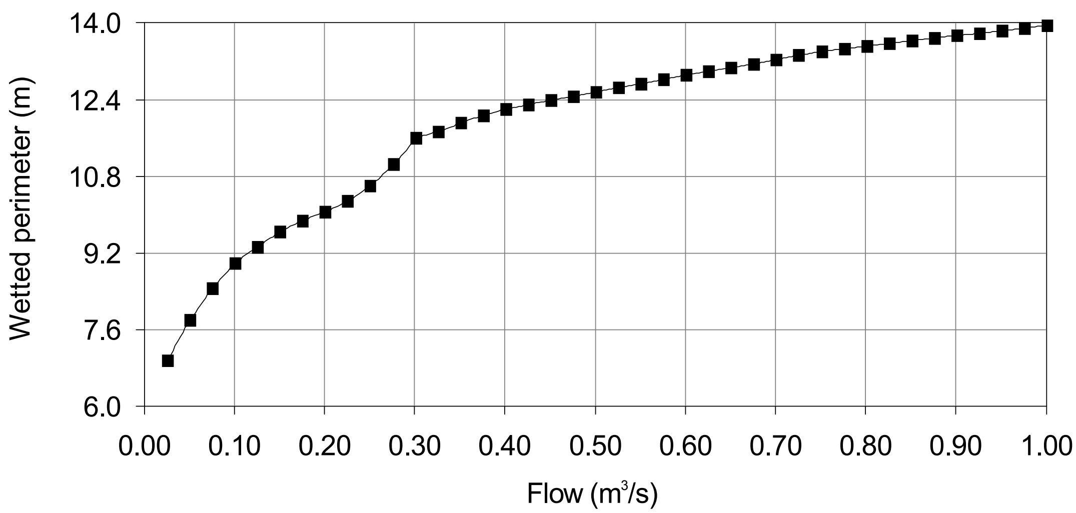


Figure 4. Wetted perimeter of the stream channel at Humbie over a range of low flows.

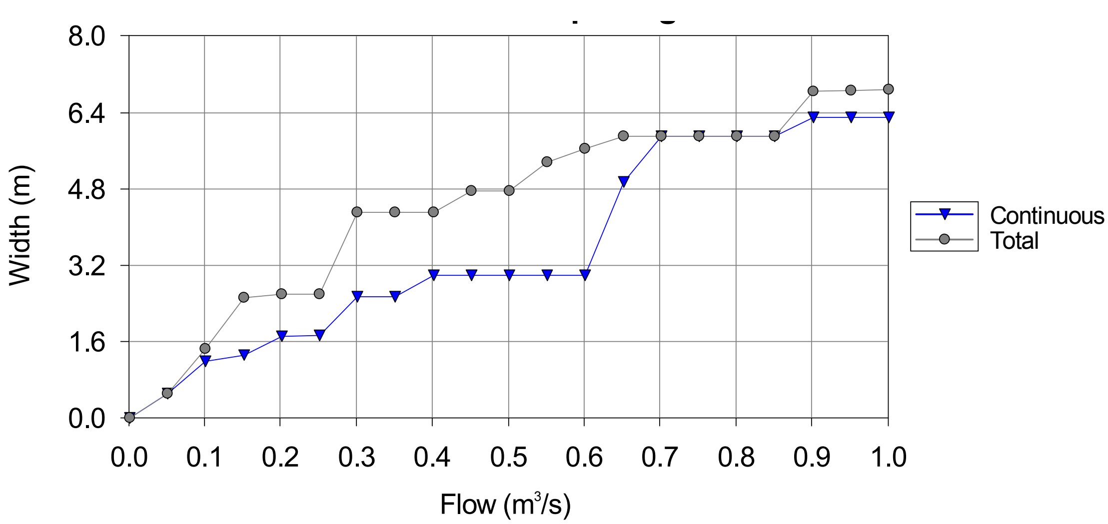


Figure 5. Minimum wetted channel width at Humbie over a range of low flows.

4. References

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